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HUNGARIAN INVESTIGATIONS IN CYBERNETICS.

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HUNGARIAN INVESTIGATIONS IN CYBERNETICS.

[Following is the translation of an article by Rezso TARJAN, published in Magyar Tudomany (:Hungarian Science), Budapest, 1960, No. 3, p. 135-151].

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The Presidium of the Hungarian Academy of Sciences discussed last year the status of the research in cibernetics in Hungary. Since this topic can certainly appeal to the interest of the Hungarian scientific public opinion, we shall briefly review the situation of cibernetics research currently conducted in Hungary.

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Although isolatedly and often in a non-conscious form, researches of cybernetics or related topics had already begun in Hungary in the early 1950-ies. In our country, just as much as in the Soviet Union and in the other countries of the people's democracy, the investigations were intensively difficult due to immaturity and to the well-known dogmatic point of view. A turn came in 1955 when in the U.S.S.R., S.L.SOBOLEV, A.J.KITOV and A.A.LYAPUNOV (See Note) unmistakably clarified the importance of cybernetics research in methodology [NOTE: See their "Main features of cybernetics" in Voprosy filosofii(:Problems of philosophy) 1955, Apr. 3]. Thereafter, the development has also started in our country.

In May 1956, at the Hungarian Academy of Sciences (hereafter abbreviated to MTA, Magyar Tudomanyos Akademia), Academicians Kalman LISSAK, and Stephen BARTHA, and the writer of this review submitted their accounts, on the basis of which--with the participation of the now deceased Academician Bela FOGARASI-- a closed private discussion was held about the biological, philosophical, respectively technical relations of cybernetics. The final conclusion of the discussion can be comprehended in the following:--at present it is still early to question whether cybernetics is an independent branch of science or not; at the present time, a uniformly definable subject matter and characteristic problems have still not developed in cybernetics. What is the most characteristic for cybernetics as a scientific investigative trend, it is the extremely close, organic collaboration of technical, biological, physiological and mathematical experts for the study of the functional principles and behavior of highly organized systems. The opinions of the participants in the discussions agreed upon the fact that, on the basis of foreign experiences, such a complex collaboration

can bring results which are extremely useful anyhow, and are not only scientifically interesting, but also have considerable advantage for the practice, even for the national economy. Hence, the participants held it desirable that the collaboration should be organized among the national experts as soon as possible.

A little while later, on 1 September 1956, the Presidium of MTA has organized the Cybernetics Research Group of the MTA which, due to the events of counter-revolution, could starte its activity only in April 1957. The international experience of the three years which have passed since, is a proof that the justification of cybernetics as an independent scientific trend cannot be questioned any longer. Among others, this is shown also by the fact that already in 1956, in the Belgian Namur, the International Association of Cybernetics was founded which, in September of the past year, has already organized its second international congress with the participation of a great many people.

One of the experiences of the congress has been that, in view of the actual results, the disputations about the definition of cibernetics are kept in the background for a while. One reason of this is evidently the extraordinarily rapid tempo of development due to which the systematization of the contents of cybernetics and the elucidation of its relationship with the other branches of science is hardly possible at present. If it comes to the question of definition, a part of the scientific investigators-- perhaps rather for reasons of comfort than on the basis of a thorough deliberation-- will accept the original definition of WIENER[2] (NOTE: See his "Cybernetics"), according to whom --as well-known-- cybernetics is the theory of control and communication in the living organism and in the machines. In any case, all authors are in agreement that one of the most important problems of cybernetics is the theoretical and experimental study of the qualities of such highly organized automatic systems which, in some form or another, are working with or employing informations for control. Consequently, for instance, S.L. SOBOLEV and A.A.LYAPUNOV include in the sphere of cybernetics <u>also</u> all those technical, mathematical and other disciplines as for instance the theory of games, the operational research, etc., which may play a role in the control functions of such complicated systems and can be used to advantage. (NOTE 3: See their monograph "Cybernetics and natural sciences; materials of the All-Union conference on philosophical problems of natural sciences; Moskva, 1958). This does not exclude, however, rather presupposes that these spheres should be also treated as independent, separate fields of science.

On the basis of these statements, it is not surprising that, during the past three years, in Hungary the researches which are conducted at various places in cybernetics or in relation with this discipline are still not forming a field where research would be harmonized organically along uniform points of view. This will evidently require a still longer period of time; accordingly, the decision of the presidium of the MTA emphasizes that there is a <u>need for active coordination at the national level</u>, which would not only coordinate the presently current

researches, but, to the extent of the country's material sources of energy, it will also initiate the start of research works which are new, have the character of basic research, but at the same time are also important for the people's economy.

Inspite of the difficulties, it can be stated that in our country during the past three years three centers of gravity developed locally:- at Budapest, at Szeged and at Pecs. The researches at Budapest are conducted first of all in connection with the technical relations of the electronic computers, with the mathematical problems of cybernetics and with the various, mostly national economical applications; at Szeged the main effort of the researches is in logics, while the team operating at Pecs is engaged in the physicological relationships. Without claiming completeness, we may summarize the hitherto achieved results as follows.

II.

The most prominent result which was born in our country since the counter-revolution is undoubtedly the fact that in the Cybernetics Research Group of the MTA the construction of the M-3 electronic computer has been finished by the end of the past year.

Since we have already described the functional principles of the electronic computers in a previous article (See my "Main problems of Cybernetics" in Magyar Tudomany (this journal) 1956, No. 1-3), we do not spend time on it at the present. The M-3,--which the coworkers of the Group described at a session in the Bolyai Association in the spring of 1959-- functions in the binary numerical system. In this system, there are only two types of numerals, the zero(0), and the unit(1); all numbers are expressed by the suitable combination of these in the same way as, in the for us familiar decimal numerical system, we express any number by the combination of the ten different ciphers(0,1,2,...9). The only difference is that in the binary numerical system, since it operates with fewer symbols, the writing of some numbers requires 3.3 times as many site values as in the ordinary decimal numerical system; hence, the number consists of a longer series of digits. The use of the binary system is advantageous for the reason that it markedly simplifies the machine in a technical respect, and it also quickens the machine's operation; it is not a disadvantage for the consumer at all since the numbers are communicated to the machine in the ordinary decimal system, and the machine itself will carry out the transfiguration into the binary system and/or the re-transfiguration into the decimal from the binary. The M-3 works with 31 place values of which one represents the sign of the number, while the rest represents the number proper. In the decimal numerical system this corresponds with an eight-figure number, which is sufficient for practical purposes.

That part of the machine which carries out the computations themselves, the so-called arithmetical unit is relatively rapid:- for the summation of two eight-figure numbers only 40 micro-secs are required

(one micro-second is one-millionth part of a second). The feeding of the data is done by means of a perforated tape, the kind which is also used in the telegraph offices, on which tape the separate numbers are represented by appropriate combinations of holes; the results are written by an electric typewriter controlled by the machine, and they are in the decimal numerical system.

Two factors restrict the exploitation of the relatively rapid arithmetic unit of the machine; these factors are connected with the fact that the so-called "memory" unit of the machine, i.e., that one of its parts which stores the initial data required for the computation, and the intermediate results of the computation as well as the final results until the moment of its recording on paper, is the so-called magnetic drum. This is in fact a special magnetophone in which, in distinction from the regular magnetophones, the magnetic coat is located not on a tape but on the surface of a cylinder which is rotating at a speed of 3000 r.p.m.; the "inscription" and/or "reading" of the data, which in a regular magnetophone corresponds with the recording, resp. the play-back, is performed with the aid of specially shaped magnetophone heads. One of the mentioned two factors is that 1024 numbers can be placed alltogether on the drum; and the other factor is that the time (p. 138) which is needed for the recording, resp. for the reading (the so-called "waiting time") is relatively long:-10 milliseconds as an average. Hence, for instance, the time requirement for the actual summation of two numbers (the "recall" of the two numbers from the memory, the summation proper, and then the placement of the result on the drum) is more than 30 milliseconds. For this reason, the average speed of operation of the machine is relatively slow:-it is 30 actual arithmetical operations per second as an average.

In the plans of the Group there are broadenings in two directions:-the construction of a ferrit-storer of rapid function on one hand, on the basis of documents arriving from the Soviet Union, in which the waiting time is not more than 10-15 microseconds, which is in correspondance with the operational speed of the arithmetic unit. The adaptation of the magnetic-tape storer of the URAL computer to the M-3(this computer is also a Soviet product) will also serve for the enlargement of the storage capacity; on this tape 40,000 numbers can be placed. The reading from the magnetic tape is considerably quicker than from the perforated tape. Thus, it is expected that the average operational speed of the machine can be increased to 1500 operations per second. After the final construction of these, the magnetic drum between the inner and outer memory will assure the required transition, the required connection.

As so many other tools of modern technology, this machine has been also built with the friendly help of the Soviet Union. This was manifested not only in the completely gratis availability of the full documentation, but also therein that it was made possible that the members of the Group could study the operation of the original machine at site, and that we have also obtained a great help in securing a part of the required components in kind. Thereby, in our country the facility was created the first

time for the solution of a number of problems, equally important theoretically as well as for the national economy, whose elaboration has been simply impossible in previous times due to the slowness of the desk computers or even of the punched-card computers.

As we had already explained it in our previous quoted article, the operation of the electronic computers is determined by the program that the mathematicians elaborate in advance separately for every problem and that they put in advance, together with the initial data of the computations, into the memory unit of the machine. In the interest of the arrangement of the M-3 for practical application, the mathematicians of the Cybernetics Research Group, simultaneously with the construction, have already drawn up the programs of those most important numerical methods which in all likelihood will be necessary for the prospective tasks. These can be roughly divided into three large groups. To the first group belong the often used so-called elementary functions (e.g., log x or sin x, etc.). In contrast to the human computational methods, the machine does not look these up in tables, but, if it needs some values, it stops the run of the main calculation, it computes the required value, then it returns to the calculations proper. To the second group belong the typical cases of the technical and scientific computations. The matter is here first of all about the various differential equations (ordinary and partial differential equations) for the solution of which a number of various numerical methods are in existence, each with its own characteristic field of application. To the third group belong the various economic (people's economy planning) and business management tasks whose characteristic feature is that for their solution either one has to solve systems of linear equations containing a very large number of unknown quantities (the number of unknowns can be 40-50 generally, but even ten times as much in a number of instances), or it is the question of problems requiring another, mathematically similar technic, as for instance in case of the so-called linear programming, which will be mentioned later on. (p. 139) As it is well-known, the preparation of the programs is an extremely tedious work which includes very many chances of error. This can be helped in two ways. One is the so-called method of sub-routines whose essence is that those partial calculations which equally occur in all sorts of problems (as e.g. the calculation of log x or of sin x) are prepared in advance and they form a so-called library of sub-routines from which the program of the always concretely given problem can be prepared simply and quickly. Partly this is also the purpose of the programs prepared in advance in the Cybernetics Research Group. Yet, the solution in a proper sense, -- which has great importance for both the practice and the science, -- consists in letting the computer itself calculate the program automatically. In this respect a standard method could not develop, even for the very reason that the instruction systems of the individual computers are different, and thus the concrete methods must be also different according to the instruction system of the machine, first of all according to the number of headings (titles) in the

instruction. Ladislaus KALMAR, corresp. member, director of the Department of the Theory of Mathematical Logics and Mathematical Machines of the MTA's Mathematical Research Institute functioning at Szeged, is engaged in the problems of the automatic programming of the M-3. At the requiest of Prof. LYAPUNOV, Kalmar will give also an account about the existing partial results of his work in the collection "Problemi Kibernetiki" to be published in Moskva.

Here we should also mention the computer with receiver which, at the Chair of Wire Wave Communication Technics of the Technological University at Budapest, Ladislaus KOZMA, Dr of technical sciences, has planned, and, with the material support of the Class of Technical Sciences of the MTA, has finished in the summer of 1958. The machine, which is entirely of independent planning and which includes many technically genial and original solutions, was meant to serve for instruction. The feeding of the numbers is done manually with the aid of a set of keys. The machine is a so-called fixedly programmed machine, with one heading, parallel operation, and with sutomatic setting of the decimal point; with such machine, the program is perforated upon a roentgen film, similarly to the punched-card principle, and this film is then automatically read by the machine in the proper sequence. The transcription of the results is done by a typewriter which was domestically changed for electric control. The practical employment of the machine is first of all restricted by the small storer which is suitable for only 12 numbers, each being an eight-figure number; the storer is provided with receivers. In spite of this, it is just the same kind of stuomatic, program-controlled computer as its larger electronic brothers, and -- aside from the modification of instruction -- it can do all those operations which are performed by the electron machines. Within the limits of its storage capacity, it is also suitable for the performance of practical calculations of small volume (e.g., preparation of tables), as this has been already done in a few cases for several other Chairs.

Similarly at the Budapest Technological University, at the Mathematical Chair of Electric Engineering, with the guidance of Stephan FENYO, lecturer and director of the Chair and candidate of the mathematical sciences, an electric model has been built which finds the complex roots of algebraic equations of as much as the sixth power by the analogy method; this can be used, for instance, for the examination of the characteristic equations of automatic systems.

III.

As long as the M-3 remains the only electronic computer in the country, the main task of the machine will be in all probability that it should help in the solution of such national-economically important tasks, requiring a lot of numerical calculation, which, in addition to the fundamental importance, will also bring a large profit for the people's economy. Accordingly, in the Cybernetics Research Group, with the guidance of Stephan ACEL, a special division is engaged in the task to prepare the M-3's

application for the elaboration of national economical and business management problems. Among the coworkers of the division, first of all Bela KREKO, lecturer of the Karl Marx Economy University, has conducted partly thema-detecting, partly methodological studies, related to the application of the mathematical methods to problems of the people's economy, or to such a definition of them that they could be solved with the available concrete machine. Thus, for instance, studies were made in reference to the programming of iron-smelting, to the optimum organization of the transportation of coal and of other fuel, to the determination of the optimum production program of paper manufacture, etc. Besid the concrete economic advantage, in a scientific point of view these examinations promote the construction of the mathematical model of the mentioned people's economic activities.

From the aspect of mathematical methods, the just mentioned tasks are so-called linear programming tasks. The question is here essentially that different, mutually dependent economic activities are to be so harmonized that some kind of appropriate, well defined economic index (e.g., the self-cost of production, or the pure economic achievement) should be optimum (e.g., the cost of production as small as possible. In other words:-e.g., the production program of a plant (or operation) should be so determined that, with a given machine capacity and material supply and manpower, the cost of production should be as small as possible. Hence, we have the term "programming". The term "linear" indicates that in the calculations at the first approximation, it is presumed that the cost of production is a linear function of the separate factors of expense, i.e., that it is directly proportional to them. Of course, in the generalized case this is not so, for instance, in the case when the plant must also resort to overtiming for which progressively rising wages must be paid. Hence, the linear programming method is a special case of the general methods of mathematical programming. Yet, the method can be used with very good result in a considerable number of the practically occurring questions, and it often leads to really large savings in the people's economy.

A typical case of such problems, to which the method is applied widely and with very good result, is the so-called transportation problem. The essence of this can be best understood by the following example. Let us imagine that there are three brick-works (A, B and C works) in the area of a county which produce 900 000, 400 000, resp. 800 000 bricks during a certain period of time. The factories transport the bricks to five building operations the demand of which is (1) 300 000 pieces of brick, (2) 500 000, (3) 400 000, (4) 600 000, and (5) 300 000. In other words, the total production of the brick-works is just covering the total demand of the constructions. Of course, this is generally not so in reality, yet, in the example we do not care about it for the sake of simplicity. Since the individual constructions are at different distances from the separate factories, at the national economic level the total cost of transportation depends on the fact which brick-works will transport how

many bricks and whereto. The transportation expenses of the separate relations per 1000 bricks are given in the following Table, in arbitrary units: (p. 141)

Brick-works	(1)	(2)	(3)	(4)	(5)	Total capacity in 1000s
	Transportation cost / 1000 bricks					
(A)	10	20	5	9	10	9
(B)	2	10	8	30	6	4
(C)	1	20	7	10	4	8
Total need in 1000s	3	5	4	6	3	21

The transportation experts have to solve such and similar problems day after day; of course, experience means a great help for this. Yet, if the same problem is solved by computation, the saving is often surprisingly large. In the just mentioned example, for instance, we may convince ourselves by simple trials that one of the <u>possible</u> transportation plans is the following:

	(1)	(2)	(3)	(4)	(5)	Total trans-portation
(A)	3	5	1	0	0	9
(B)	0	0	3	1	0	4
(C)	0	0	0	5	3	8
	3	5	4	6	3	21

On the basis of the above quoted cost prices, the total cost of this transportation plan is 25 100 units. Yet if we compute the optimum solution, we get the following plan of transportation:

	(1)	(2)	(3)	(4)	(5)	Total trans-portation
(A)	0	0	4	5	0	9
(B)	0	4	0	0	0	4
(C)	3	1	0	1	3	8
	3	5	4	6	3	21

With this variant, which is the optimum, the total transportation cost is only 15 000 units, i.e., in contrast with the previous transportation plan established by trials, it means a saving of almost 40%. Of course, in reality it may be the question not only of a transportation of bricks, but also, for instance, of coal, or, at the peak traffic in the fall, of grain and sugar-beet. Hence it is understandable that such methods have a great importance for the national economy.

The methods for the solution of such and similar types of problems are analogous with the methods of solving the linear systems of equations; but in the practice, the solution is made markedly difficult because the number of the unknowns is very large; (p. 142) in the just described simple, artificially constructed example there were 15 unknowns. The solution requires by all means very rapidly operating electronic computers; even with their use, the work may sometimes require several hours. Hence, it is of decisive importance that such mathematical methods of solution are found which will simplify the needed methods of calculation and will possibly reduce the volume of calculations. Here, great importance comes to those propositions (theorems) of theoretical graphs science which have been already reached by DENNIS KONIG and applied by Eugen EGERVARY to the matrices occurring in linear equation systems. On the basis of this, the so-called "problem of added order" can be solved relatively simply. The problem of added order is a special instance of the general transportation problem, and it differs from it therby that each producing place makes one unit and they must be distributed to the receiving places of identical number in such a manner that some kind of cost must be as small as possible. The methods which are based upon the Egervary propositions are called generally the "Hungarian method" in the international technical literature. In his latest works, Egervary further developed the mentioned results (which originate still from 1931) to the general transportation problem, and he indicated such a method which is appropriate for the considerable reduction of the otherwise very voluminous numerical work.

The just mentioned problems are chiefly of the nature of business management. From a national point of view still more important are the problems of a people's economic character. Experiments have been continued for more than a hundred years to their treatment with mathematical methods, mainly in the direction of establishing the mathematical model of the totality of a given national economy. The model which was elaborated by W. LEONTEV[5] national economist of Russian extraction, now living in the U.S., is actually the mathematical definition of the so-called chessboard method which has been developed in the U.S.S.R. in the mid-twenties. (NOTE 5: See his "The structure of the American economy 1913-1939; 2. ed., N.Y., Oxford Univ. Pr., 1953). With this model, the given national economy is split up -- in such a way of splitting as required by the purpose of the examination -- into sectors (e.g., coal mining, manufacture of tool-making machines, textile industry, etc.). Separate sectors are the export, import, and the domestic utility services, resp. the consumption (as a sector producing manpower). Aside from the transit entries of warehouses, the production of the various sectors is used up

by the other sectors, i.e., the individual sectors mutually depend upon each other.

If we presume that the technology of production does not change during the examined period of time (e.g., in a year), furthermore, that the output of the individual sectors is the linear function of the various inputs (which is of course true in the first approximation only), the model leads to a linear equational system whose solution will essentially give the distribution of products in harmony with the given technology, resp. with the total production; yet, useful conclusions can be also drawn in a number of other connections (e.g., determination of quotas, review of the consequences of modifications in plans, accuracy of the price system, etc.). In the practice, the analytical splittings are usually at least of 40 sectors, but rather of 100-200 sectors. Since for the solution of for instance an equation system with 100 unknowns a volume of one million multiplications is needed, it is apparent that it is not worth while to attempt the solution with manual methods. The first actual numerical examinations were made possible in fact by the development of electronic digital computers; even with electronic speeds, the numerical working up of one or another larger problem, perhaps presented in several variants, may require 8-10 hours of operation. Although (p. 143) the suppositions of the Leontev model have only a strongly approximative character, its importance for the socialistic planned economy is indeed obvious:-it makes possible that, instead of estimations, the economic plans can be prepared on the basis of approximately accurate computations, in several variants according to the need out of which the best variant can be then selected relatively simply. The KKCs (Kibernetikai Kutato Csoport: Cybernetics Research Group)'s Division of Application, in cooperation with the National Planning Bureau and partly with the Prices Bureau, will also prepare the machine solution of such problems.

It is good to see that recently the interest in the mathematical economic questions strongly increased among the economists as well as the mathematicians, one sequela of which is the gradual construction of collaboration between mathematicians and economists. One visible manifestation of this is for instance that mathematicians are also employed in the MTA Institute of National Economics, while an economist-mathematician group was organized in the MTA Mathematical Research Institute not so long ago. The first national theoretical results can be found in a 1956 joint publication of Alfred RENYI and Andrew BRODY[6] in which the problems of price regulation are discussed (NOTE.6: See their: "The problem of price regulation." Mat. Kut. Int. Kozl. (Publications of the Mathematical Research Institute), 1956, vol. 1: No. 3, p. 325-326.). In the National Economy Institute of the MTA, Andrew BRODY is investigating, with the Leontev model's matrix, the possible national economic interpretation of the greatest self-value, while George KONDOR has solved a transportation problem in the sugar industry by quadratic programming, which shows the advances in the linear programming method. In his most recent work7, (See his "Saving in business and money economy" in MTA Mat. Kut. Int. Kozl., 1959, vol. 4, No. 1, 11-14), Andrew BRODY has demonstrated,

again on the basis of the Leontev model, that the saving at the plant level does not always mean also a simultaneous saving in national economy. Here, it should be also mentioned that, in 1957, Bela KREKO and Zoltan BACSKAI published jointly a book with the title "Introduction into the linear programming", which is at a high level.

An interesting and important initiation is the Conference on Traffic Cybernetics arranged in March of this year by the Society of The Sciences of Traffic and Communication Construction, with the participation of foreign delegates, whose most important paper was read by Prof. I. J. AKSONOV on the locomotive without engineer, completely automatic, and already being in the testing stage in the Soviet Union. The Hungarian participants examined the applicabilties of cybernetics in various fields of communication. The significance of the Conference is mainly in the fact that it called attention to a number of new, interested, capable experts. Its most important result can be so summarized that in the interest of cybernetics and, within this, of the application of the electronic computers in communication, the preparation of appropriate government measures has begun.

As a cheerful fact can be also recorded the circumstance that -- although not yet with the required organization and intensity -- there has been also made a start in the teaching activity related to electronic computers. At the Szeged University, Ladislaus KALMAR, corresp. member, holds regular seminars of programming, and/or lectures with the title "Programming of automatic computers". At the Faculty of Natural Sciences of the Lorand Eotvos University, Francis SANDOR, scientific collaborator of the KKCs, (p. 144) as an external lecturer, held lectures in the first semester of 1958. The collaborators of the KKCs organized a course of programming, which consisted of 38 lectures and was attended by a large number of participants. Notes were also prepared on the material of the course for the participants; they include also the description of the machine, in addition to the programming of the M-3. The teaching of the technical questions of the electronic computer was given a place of a facultative subject in the curriculum of the signal technology at the Budapest Technological University from the 1959/60 year of instruction on.

The teaching work is markedly made difficult by the fact that a suitable Hungarian technical book (aside from the lecture notes prepared after the introductory lectures held by the author at the Postgraduate Engineering Institute) is now unavailable, while the majority of the books on computers written in foreign languages treat the structural elements, the questions of logical structure not generally, but mostly in connection with a single concrete machine. Thus, naturally, these books put in the foreground those methods of solution which are used in the given machine. For this reason, the program of the lectures at the Technological University was so compiled that, in connection with both the separate structural elements and the logical structure, those questions came into the foreground which are common to all computers, and which, aside from the computers, can be also applied in other relations as, e.g.,

in the electronic telephone centers and in the various types of numerical controls. With the use of the experiences of the lectures, the writer of this review is working on a textbook, useful also as a handbook, under the title "Technics of electronic coupling and its practical employments" whose sphere of topics includes the electronic instrumentation of the tasks of coupling and storing, then their use in the electronic computers and information-elaborating machines, in electronic telephone centers as well as in automatic systems for the performance of tasks of production technics and guiding technics.

IV.

In the introduction we have already mentioned that the idea of quantity of information is one of the central concepts of cybernetics. Since we have already described the most important facts of the information theory in the quoted previous article, we do not dwell now on the details, and we mention only that much that the measure of the value of quantity of information--, which is called entropy for its identity with the entropy of thermodynamics--, is usually given for two kinds of transmission method. In one of them, the transmission occurs by means of signals continuous in time, as for instance in the radio with the transmission of music, while in the other the transmission occurs by so-called discrete, (i.e., in time separated from each other) impulses, as for instance in the telegraph. The measure of the quantity of information is given in both cases by a formula of similar structure, but in one case it is a question of the integral, and in the other case a question of summation.

As we have mentioned it in the cited article, the concept of the quantity of information has been introduced in 1949 by Claude SHANNON, well-known American mathematician, on the basis of the previous works of SZILARD and HARTLEY. But its definition was not sufficiently precise from a mathematical viewpoint. The mathematically also correct discussion of the question in case of discrete transmission has been given by A. J. HINCHIN, Soviet mathematician. Alfred RENYI, Academician, in an article written jointly with John BALATONI[8] (See their "The concept of entropy" in MTA Mat. Kut. Int. Kozl., 1956, vol. 1: No. 1-2) (p. 145), in connection with the continuous transmission, gives an accurate definition, and introduces an important new concept, the concept of the entropy of probability calculation. This article has been translated since into German, too. In a newer work [9] (See A. Renyi "On the dimension and entropy of probability distributions" in Acta math., 1959, vol. 10: fasc. 1-2, p. 193-215), he proves newer propositions related to the dimension of entropy, and elucidates the relationship with the E-entropy introduced in 1956 by LOLMOGOROV. In a study of his now in the press, Paul ERDOS, corresp. member, with the aid of an older proposition of his in the number theory, demonstrates in a manner essentially simpler than the hitherto known demonstration of the HINCHIN-FAGEEV theorem that the Shannonian

devinition of the quantity of information, in case of discrete transmission, is the only one which agrees with the known postulates. He has also held a lecture about his results at the Second International Conference on Information Theory at Praha.

As it is well-known, it was BRILLOUIN who in a number of articles and in a book published in 1956 (NOTE: See his "Science and information theory", monograph, 1956) called attention to the fact that the analogy between the entropy of the information theory and the entropy of thermodynamics is not only formal, but the information quantity actually represents negative entropy.

In our country, Emerich FENYES, Dr of the physical sciences, is engaged in the physical aspects of the information theory. The essence of his new findings, now in the press, is the following:-The present generally accepted opinion considers the resolution of the thermodynamical, so-called Gibbsian paradox therein that this occurs in the classical statistical mechanics. But the classical statistical mechanis is only an approximation to the true quantum-mechanical statistics; but, in the latter (which accurately represents the micro-relations) the Gibbsian pardox does not occur.

Contrary to this opinion, it can be shown that, with the use of the entropy of mixture in the information theory, the Gibbsian paradox will lose its character of paradox even in the classical statistics because, under various conditions of "controlling", different entropies have to be attributed even to the same system. In his second finding, Emerich Fenyes shows that the entropy-decreasing effect of the measurement information can be indicated in a way simpler and physically also more consequent than the method of Brillouin. His manuscript of an article about this question, opening a discussion with Brillouin, is now in preparation.

V.

Cybernetics has also a close connection with mathematical logics. Mathematical logics, as its name shows, treates the questions of logics by mathematical methods. In the simplest case -- this is the so-called calculus of sentence -- each proposition is symobolized by a single letter (e.g., A = the table has four legs), and it is examined that, if we connect different propositions with each other -- e.g., by the "And" or the "Or" conjunctions -- as in the case of the so-called logical conjunction or disjunction -- in what manner will depend the truth or falsehood of the complex proposition, the so-called logical value, (which is usually marked by 1 or 0) upon the circumstance that the conjoined propositions in themselves had been true or false.

The circumstance that any kind of complicated announcement is only true or false, i.e., its logical value can be only 1 or 0, has made it evident, already before almost a hundred years, that such machines should be constructed which "compute" the logical value of complicated logical expressions, i.e., which establish that the composite statement

is true or not true. In principle, the possibility for this is given thereby that there are a number of such partly mechanical, partly electric or electronic instruments which can exist in two, and in only one of the two, different states one of which can be identified with 0, and the other with 1. Ultimately, the electronic computers are also based upon this. The first such logical machine, which in accordance with the technology of the era was still functioning with mechanical means, has been already constructed in 1870 by STANLEY JEVONS. Since then, these machines are acquiring more and more importance, even in the practice.

In our country Tihamer NEMES, Dr of technical sciences, was the first who was engaged with the question of instrumentation of the problems of logics; after his earlier experiments, in 1953 he constructed the mechanical model of a logical machine, and has also laid down the principles of the electronic realization. (NOTE: See his "Logical machines for recognizing class and causal relations genetically" in Acta techn, 1953, vol. 7: No. 1-2, 317 l.)

In the Postgraduate Engineering School he held a lecture series on the various logical machines, resp. on the cybernetic animal models; he published notes about this, (NOTE 12: See his "Logical machines", pamphlet of the Postgraduate Engineering School, No. 3355, 1955). Thereafter, an the basis of the notes, he wrote a book with the title "Cybernetic Machines" which is to be published by the Publisher of the Academy. The book treats in detail not only the logical machines of mechanical execution, which nowadays are of historical interest (JEVONS, MARQUAND, etc.) and the logical machines in the strict sense, but it also includes the control work of the electronic computers as logical machines, the translating and game-playing machines, the apparatuses which model the various biological functions, and it deals with the principles of function of the artificial letter-reading, shape-recognizing and dictation-writing machines, too.

In the field of the instrumentation of logical problems, the most important domestic experimental result is the logical machine which Ladislaus KALMAR, corresp. member. has planned and executed with the aid of Daniel MUSZKA. This is the first domestic model of this type. In the construction of the machine, he follows the principles of the first type of the well-known Ferranti logical machine, that is, he instruments the elementary logical operations in the form of the so-called pluggable boxes. Its construction started in the fall of 1956 with the material support of the KKCs, then, after the organization of the appropriate division of the MTA Mathematical Research Institute, it was finished within that division. Its essential and patent-claimed novelty consists therein that the pluggable boxes serving the instrumentation of the elementary logical operations contain wires exclusively. Therby it is possible that the logical variables are represented not by a single contact (a pair of wires) but by a switch contact (triple wires, three-poles). If the logical value of the variable is "true", the center contact is standing in metallic connection with the lower wire, in the opposite case it touches the upper wire. The first illustration, for instance,

illustrates such an instrumentation of the quadruple logical conjunction. We may easily find out that in the outgoing triple line the central line will be then, and only then, in a conductive connection with the lower line, if the central lines are in the same position at all four ingoing triple lines, as it agrees with the definition of the logical conjunction. Similarly, merely by wiring we are able to instrument also the other elementary logical operations.

(p.147) When constructe for a certain adequate capacity, the machine can be used for the solution of a number of tasks which are also practically important. One of the important fields of its application is, for instance, the experimental study of receiver systems (without delaying mechanism) for the purpose to see whether they correspond with the prescribed conditions of coupling. The author demonstrated the machine to many interested persons here and abroad, thus in the Soviet Union, at the International Mathematical Congress at Edinburgh in 1958 [13], and at the Second International Congress of Cybernetics at Namur[14] as well as in China (NOTE 13: L. KALMAR: "Problems concerning the conductivity states of multipoles". Internat. Congr. Mathem., Edinb., 1958; NOTE 14: See his "A new principle for the construction of logical machines", Second Congr. Internat. of Cybernet., Namur.

In connection with the experimental researches of the receiver systems, Rose PETER, Dr of the mathematical sciences, has conducted important, unfortunately still unpublished investigations which she reported at the Mathematical Colloquium held in September 1959 at Balatonvilagos. The systems of receiver contacts are usually treated together with the previously mentioned methods of the calculus of sentence. Rose PETER proves that the methods of the receiver contacts may be also treated in a different way, namely together with the theory of recursive functions.

Valentin DOMOLKI, young mathematician of the MTA KKCs, has given a definition of the concept of event which plays an important role in the finite automatic machines. His definition is more accurate than the current one. He reported this at the jubilee congress of the Farkas Bolyai Mathematical Association at Szeged in 1957. In this case also, it would be desirable to have the results published as early as possible.

The logical machines hitherto constructed in our country, respectively abroad, inspite of all their advantage have the disadvantage that they are able to solve only the problems occurring in the above mentioned calculus of sentence. Yet, the calculus of sentence, since it does not distinguish between the various parts of the announcements, is fit only for the accurate definition, respectively for the solution of relatively simple logical problems. If however the matter in hand is such questions as the reasoning (syllogism), where for instance such sentences are found as: "every man is (mortal)", or such as "there is such a man who..." etc., the simple calculus of sentence will fail, and new methods are needed. These methods already belong to the so-called calculus of predicate or to the logical functional calculus which on one hand separates the subject and the predicate in the simple sentence, on the other hand introduces two important functional signs, the so-called quantors.

(p. 148) One of them is the so-called universal quantor which marks that the subsequent statement is true for all subjects (for all values of the logical variable); the other is the so-called existential quantor which signifies that there is such a subject (logical variable) for which the subsequent statement is true. Scientifically it is an interesting and very important problem to construct such a machine which is suitable not only for the machine solution of the calculus of sentence but also for that of the logical functional calculus. If we call/first-type logical machine the one which serves for the purposes of the calculus of sentence, evidently the machine for the purposes of the logical functional calculus will be a logical machine of the second type. The author of this review, in one of his works in the press[15], shows that the logical machine of the second type is actually a special digital automaton, and he also gives the technical requirements which may form the basis of the concrete construction (NOTE 15: S. TARJAN: "On logical machines" in Acta techn. , in the press).

It is easily apparent that the logical machines of the second type -- if the basic premises, the legitimate rules of reasoning, the proposition to be proved and the procedure of demonstration is given--, with the elaboration of a suitable program, may be used for the control checking of the proof (verification). Yet, for the construction of proofs they can be employed only then if certain heuristic principles are built into the program in advance, -- as this is shown by a few newer findings. [16, 17] (NOTE 16: A. NEWELL-H.A. SIMON: "The logic theory machine". IRE Transact. on Inform. Theory, vol. IT-2, Sept., 1956; see also the later works of the authors. -- NOTE 17: H. L. GELERNTER: "Realization of a geometry theorem proving machine". UNESCO ICIP paper No. 1, 6, 6 (June, 1959). The programming (hence ultimately an operation of a deductive character) will however still remain necessary, without any change even in this case.

Thus, it can be easily seen that both the first and the second type of the logical machines are essentially of deductive character, in the sense that they can do only the programmed bi-valent logical operations. The first construction of some proof, however, the so-called "intuition", is not done in a deductive way mostly, but by induction, where the plausible reasoning in POLYA's sense is playing a great role. (NOTE 18: G. POLYA: "Mathematics and plausible reasoning I-II", monograph in two volumes, see chiefly in the second volume). This requires the associative readiness of the living nervous system whose physiological basis -- as far as it is known -- is the recognition of the identity (similarity) of shapes or even of entire situations. The author proves in an earlier publication of his[19] (NOTE 19: See his "Neuronal automata". Cybernetica, 1958, vol. 1: No. 3, p. 189-196) that in principle the present-day digital automata are unable to do this. Those still hypothetic machines which are able to solve the logical problems by inductive methods are evidently a third class of the logical machines; on account of the properties of their structural elements they may be called neural automata. If we are postulating the m

most important few properties of the neurons, -- which can be indeed also instrumented with electronic means relatively easily -- , and if we generalize the concept of "similarity" (identity) so that not only the fact but also the dimension of the similarity can be defined, it is possible to set up such an organization (neural meshes) which are able to irradiate the effects originating from suitable receptors; on the basis of this, with the aid of common partial nets -- in the sense of the generalized definition -- they will perceive similarities. Moreover, on the principle of reverberation, they will be also able to deal with memory tasks. Yet, the ability of irradiation and of memory together is the basis of association, and ultimately therefore the basis of the formation of the (p. 149) conditioned reflexes and of the learning, too. One of the interesting properties of the neural automata is, which follows from the above, that they must be conditioned, instead of programmed by the usual logical way.

About these problems, and about the intermediate achievements, the author held lectures in 1957 at the Cybernetic Seminar of the Moskva State University, then in 1958 at the International Mathematical Congress held in Edinburgh[20], and at the Second International Congress on Cybernetics[21], which will be published in the Acta of the congress. (NOTE 20: See his "Neuronal automata". Second Internat. Congr. on Cybernetics, Namur, 1958, Sept., 3-10; NOTE 21: See his "On the instrumentation of logical problems", Internat. Cong. of Mathematicians, Edinburgh, 1958).

VII.

The problems of the neural automata lead us over to the biological problems, specifically to the most important problem of cybernetics, to the mechanism of the logical structure and signal transmission in the brain cortex and generally in the central nervous system as well as to the regulatory functions of the processes occurring in the living body. As well-known, exactly such investigations of partly biological, partly technical nature led to the formation of the sphere of cybernetics in the present sense. In this field, the team which is working at Pecs achieved prominent findings , even from an international point of view.

John SZENTAGOTHAI, corresp. member, with his researches done since 1944, [22]succeeded to elucidate the anatomical and logical structure of the neural connections between the oculomotor muscles and the labyrinth. Aside from the oculomotor muscles, the findings can be also applied to the kinetic mechanism of organs moved with double pairs of muscles by means of articulations; namely, the given logical structure explains the important circumstance that in a muscular four a single muscle may be, in relation to its fellows, once a synergist, and once again it may do antagonistic functions. This, according to the anatomical studies, is possible by the insertion of specifically inhibiting neurons. From a technical aspect, the so obtained control system is certainly complicated, yet it is extremely flexible, and, if instrumented by appropriate means--, which is possible without any difficulty--, can be also apparently directly

applied, for instance, at the manipulators used in case of radioactive preparations. The author of this review is conducting investigations for setting up a suitable mathematical model (which is necessary, e.g., for the clarification of the conditions of stability); the investigations promise good results, but they are still unfinished. (NOTE 22: See his "Connections of the labyrinth with the oculomotor muscles". Orvoskepzes (Postgrad. Med.), 1944, No. 1).

At the transmission of information in the nervous system, the neuronal transmission of excitation has the decisive role. In this respect, Alfred Renyi and John Szentagothai gave in their joint work[23] (NOTE 23: "Transmission of excitation, its probability in the simple model of interneuronal synapse with convergent connection" (Preliminary publication) MTA Mat. Kut. Int. Kozl., 1956, 1: No. 1-2, 83-91) for the transmission of excitation such a mathematical model of probability distribution on the basis of which the findings are in very good agreement with the experimental data.

(p. 150) Very interesting results came from the investigations of John Szentagotai and George SZEKELY in relation to the innervation of supernumerary limbs. The investigations in connection with the innervation of the supernumerary limbs have been conducted with a very fine experimental technic. They unequivocally prove that even from a limb which is grafted at a site other than the normal (e.g., on the back of a chicken) informations will enter into the cerebral cortex; the responsive reactions, respectively the stimuli provoking the responsive reactions, are already returning to the real (normal) limb. Contrary to the hitherto held assumptions according to which the nervous system is discriminating the various centripetal stimuli chiefly on topological principles, these investigations seem to indicate that the stimuli arriving from the various receptors are also containing some kind of specific code (which is of course still unknown for some time), by which the organism is able to correctly guide the responses provoking the reactions. Similarly extremely interesting results were reached in regard to the elucidation of the mechanism of optical orientation. By means of embryonal ocular transplantations on salamanders, it was possible to show the role of feedback in the optic orientation.[24] (NOTE: 24: J. SZENTAGOTHAI -- GY. SZEKELY "Elementary nervous mechanisms underlying optokinetic responses". Acta physiol., 1956, vol. 10: NO. 43-55.). About this problem, John Szentagothai held a lecture in October 1956 in Moskva, with great interest of the audience. The investigative methods were described by Gyozo (Victor) SZekely in a special monography.[25] (NOTE 25: "Research methods of experimental embryology". In the 3. vol. of the "Examination methods of Experimental Medicine" (A kiserletes orvostudomany vizegalo modszerei), vol. 3, p. 939-1027.). The recent results were reported, with the demonstration of films, at this years's migrating meeting of the Hungarian Physiological Association.

In his 1956 article, [26]("Cybernetics from the viewpoint of neurophysicology", Magyar Tudomany (:Hungarian Science), 1956, No. 4-6, p. 181-190), Kalman LISSAK, Academician, analyzes the importance of cybernetics for neurophysiology. From a medical point of view, he compares the functions of the control mechanisms and of the mechanisms regulating the living organism, and he point out also the essential differences which exist between the two, inspite of the functional analogies. It would very much desirable to have such comparison of scientific accuracy also from a technical point of view whose conclusions could be also used with good result in the technological practice. In his latest investigations, together with his coworkers, Bela FLERKE, Bela MESS and Stephen HALASZ, he studies the mechanism of the neuroendocrine and humoral regulations. Their detailed review, however, would be out of scope. In this field it would be exceedinly important to invite also the technical and mostly the mathematical experts so that the experimentally detected correlations could be tentatively formalized and practically employed.

The team at Pecs obtained some results in this field which arose the interest of people even outside the medical circles. These results were reported at the two-day colloquium in cybernetics held in May of this year. At this colloquium, they also demonstrated the artificial (robot) lady-bug which was constructed at Szeged by Daniel Muszka, coworker of the MTA Mathematical Research Institute, for the modelling of the conditioned reflexes. This is also based upon the principle of feedback, but in its technical details it differs from the hitherto known solutions. The model was described in a popular way in the "Elet es Tudomany" (Life and Science), respectively in the Natural Sciences Magazine ("Termeszettudomanyi Kozlony"). On the basis of the present experiences, the planning of a newer model is made which could be applied for the purposes of an auto-driving automaton.

(p. 151)

VIII.

As a final result, it can be established that the Hungarian researches in cybernetics took a developmental swing of a quick tempo in the last years, and in many cases, notable results were obtained, even in international relations. One proof of this is the healthy development of the international connections. We have to mention on the first place in this respect those co-operative contracts, which the KKCs of the MTA signed with four research institutes of the U.S.S.R. Academy of Sciences as well as with an industrial research institute. Such a contract exists also between the MTA Mathematical Research Institute and the Automatization and Telemechanical Institute of the U.S.S.R. Academy of Sciences within which they also planned the common solution of certain theoretical problems related to the receiver networks. In June 1959, three members of the KKCs participated at the international documentation conference held by the UNESCO at Paris. The International Federation of Cybernetics has three, and the British Computer Society has one, Hungarian members.

Beside these results, however, it should be also pointed out that in a number of fields the investigations have hardly begun, or not at all, in spite of the fact that the questions are partly such whose investigation, at least for a while, would not require a larger material expenditure. Among them, the problems of the machine translation must be first mentioned, which already has a considerable international literature it has serious theoretical and experimental results, moreover, with regard to the practical significance, even an international organization was established for the problems of machine translation. Another field which has a very great practical importance is the control of the production operations by means of computers. In a practical respect, here are two fields of prominent importance:-one is the numerical control of the tool-machine, which, in contrast with the hitherto used methods, solves the question of smallseries production in a very flexible and simple form; the other is related to the manufacturing processes of continuous operation (chemical plants) in connection with which both in the U.S.S.R. and in the U.S. large-scale theoretical and more and more experimental investigations are carried out. The initiation of the scientific research work in this direction is necessary and important for us in such a degree as it is possible for our forces, the more so because it organically belongs to the preparation of a transition to automation, which is one of the targets of the new five-year plan. Practically nobody is engaged in our country in those important sociological and philosophical questions which are brought up by cybernetics (e.g., the social effects of total automatization), which were however discussed in a separate lecture at the October 1958 All-Union Philosophical Conference at Moskva, and in a special section at the Second International Congress on Cybernetics. The national research of the sociological and philosophical problems is made undoubtedly difficult by the fact that between the research workers in sociology respectively philosophy and the experts in technology, and mathematics and physicology such a fruitful cooperation could not have been established until now as in other fields of cybernetics. It can be expected, however, that in the sense of the decision of the Hungarian Academy of Sciences, the nation-wide coordination, which is to be organized, will also help to get over this difficulty.

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